The DOE again is the owner and operator of this disposal site. It's a disposal site for spent nuclear fuel and high-level waste. The EPA developed radiation protection standards for the site specific to that site. And the Nuclear Regulatory Commission (NRC) is the licensing authority for this site. They would develop the licensing criteria for Yucca Mountain based on EPA's standards and would review the license application from DOE and issue the license and oversee compliance from that point.

Some key dates for the Yucca Mountain project, from EPA's point of view. . . Earlier, I noted that we had issued general standards for radioactive waste disposal that included high-level waste and spent nuclear fuel. In 1992, Congress directed EPA first to commission a study by the Academy of Sciences about Yucca Mountain. That report was issued in 1995. Then, on the basis of that report, issue disposal standards that would be specific to Yucca Mountain. In other words, these would be separate and distinct from our general or generic disposal standards. So, as I said, we issued those standards.

The standards can be divided into two components: one requirement that applies to the management and storage of waste during the operational period; and a set of standards that apply to the disposal period. The management and storage standard is that, while the site is operating, no member of the public will receive more than 150 microsieverts committed effective dose equivalent.

For disposal of waste, the period of performance that we applied was 10,000 years. There are three basic requirements. In each case, DOE must demonstrate a reasonable expectation of compliance with the limits, since absolute proof of compliance is not to be had.

All of the limits are based on the mean of the projected doses and they apply to the reasonably maximally exposed individual, or RMEI, as opposed to a population. So the first of the disposal standards applies to undisturbed conditions, meaning no human intrusion is factored into the analysis. The standard there is that the RMEI will receive no more than 150 microsieverts annually from radionuclide releases in undisturbed conditions.

Some assumptions built into this are that exposure to the RMEI is from all pathways, that the RMEI lives above the point where the contaminated underwater plume has the highest concentration of radioactive contamination, and that the diet and lifestyle of the RMEI are consistent with the town of Amargosa Valley, which is about 18 miles south of the Yucca Mountain facility, has about 1,400 residents, and is predominantly an agricultural community.

We then introduced a stylized human intrusion scenario that the DOE would have to consider. And that standard is that DOE must determine the earliest time after the site is closed that a driller could puncture a waste package without detecting the presence of the package.

If that time is less than 10,000 years, then the protection standard that applies is that the RMEI will receive no more than 150 microsieverts per year. If the time of this penetration is later than 10,000 years, DOE has to report that time in their Environmental Impact Statement. That's a report that DOE would have to prepare prior to initiating waste disposal operations. And the public is involved in the review of that document. This human intrusion scenario assumes that there is a single borehole above the facility that punctures a single waste package.

We introduced our groundwater protection standard that is consistent with the agency's standards for groundwater protection nationally developed by the EPA Office of Water. And this standard applies to undisturbed conditions where natural processes are considered and no human intrusion is assumed.

This standard is that radionuclide concentrations in a representative volume of groundwater must be less than 5 picocuries (pCi) per liter combined radium 226 and 228, 15 pCi per liter gross alpha and 40 microsieverts (:Sv) per year to the whole body or organ from beta photon radiation.

In this section, we review some other elements of the standards. Peak dose to the RMEI is anticipated well past 10,000 years, at about 100,000 to 200,000 years. DOE must calculate the peak dose to the RMEI and must identify that in the Environmental Impact Statement.

The point of compliance for the dose calculations can extend up to 18 kilometers south of the Yucca Mountain facility, which is consistent with the direction of groundwater flow and no more than five kilometers in any other direction, north, west, or east of the facility. DOE must preserve knowledge of the site. However, we did not specify any assurance measures in our disposal regulations. We left that to the licensing authority, NRC, to determine.

And lastly, factors other than hydrologic, geologic, and climate changes -- that is, natural processes -- are assumed to remain constant. The future states assumption says that drilling technologies and social and political structures are assumed to be the same in the future as they are today because they cannot be predicted with any degree of reliability.

So what happens next for Yucca Mountain? EPA has issued its standards. Our rule has been completed. The next step is that NRC will finalize its licensing criteria now that they have our final standards. They can do that by the end of this year.

The DOE is expected to recommend that Yucca Mountain be used to dispose of radioactive waste. That recommendation will go to the President and could happen by the end of this year or early next year. If the President and Congress agree with DOE that the site is suitable, they will authorize disposal and the Department will submit a license application to NRC.

However, we have been sued on our disposal standards and the Federal Courts will have to decide the outcome of those lawsuits. We don't know when they will do that. It could be spring of next year. Obviously, the outcome of those lawsuits could affect some of these other actions and their timing.

So to conclude, I'll just say that the WIPP program is a very complex project. Therefore we, as the regulators, are very active and there are a number of unprecedented, technical and policy issues that we have to confront. It's really a fascinating project to work on. For Yucca Mountain, our standards are out. We think that they are, without question, a crucial part of evaluating the suitability of the site for waste disposal and we believe that these regulations are appropriate and will be protective of human health and the environment.

Safety Analyses for Shallow-Land Disposal of Alpha-Bearing Wastes

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Abstract

Safety analyses for the shallow-land disposal of alpha-bearing wastes were performed using the deterministic and probabilistic safety assessment models. The deterministic analyses show that the dose calculation in the residence scenario is of great importance owing to the influence of daughters built up by uranium decay chain. The parameter uncertainties for the important pathways in residence scenario are estimated from the probabilistic analyses using the statistical methodology. The uncertainty analysis indicates that the influence of parameter uncertainty is the most remarkable in the estimation for the inhalation of radon gas with residence.

Introduction

“Uranium Wastes” or RI and Research Wastes represent the alpha-bearing wastes. The contaminated materials by uranium are generated through the operation and dismantling of facilities for smelting, converting, enriching etc. It is considered that there are some possibilities of safely implementing a shallow-land disposal for most of the uranium wastes because those concentration levels are distributed to be relatively low. The uranium wastes are characterized by the existence of long-lived radionuclides, the growth of daughters associated with uranium decay chain, the emanation of radon from wastes containing Ra-226 etc. To evaluate the performance of the waste disposal system over long time scales, a deterministic approach is used for quantitative estimates of peak dose to an individual. However, uncertainties with respect to parameters, scenarios etc. are inherent in the long-term assessment for uranium waste disposal. At the next step of safety assessment, it is essential to estimate the uncertainties quantitatively. JAERI has developed the deterministic and probabilistic safety assessment system to estimate the long-term radiation effect owing to the shallow-land disposal of uranium wastes.

Assessment Methodology

In this study, uranium wastes are distinguished from solid wastes such as the residues from the mining of uranium alpha-bearing ores. The major materials are concrete, metal and incinerated wastes arising from the operation and dismantling of the facilities. The amounts of uranium wastes considered in this analysis are 100 thousands m3. It is assumed that the quantities of the materials are disposed in shallow-land burial of trench. The performance of the shallow-land disposal system may be affected by two events in the future: subsequent natural process and human intrusion. The natural process leading to human exposure is represented by radionuclide migration in groundwater flow with the associated process of diffusion, dispersion, sorption and decay. There is also the possibility of inadvertent human intrusion such as house construction on the shallow repository. The scenarios considered here are both the site-reuse scenarios associated with human intrusion into the disposal site and the groundwater migration scenarios with radionuclides migration in groundwater. The events of human intrusion at the disposal site are considered to be exposure events with house construction (construction scenario) and with residence

(residence scenario). The exposure events of using river water on the basis of contaminated groundwater migration (groundwater migration scenario on use of river water) were considered to derive the upper bounds of radioactive concentration in the wastes acceptable for the LLW disposal in Japan [1] and are also referred here. Viewed from scenario uncertainty on the estimate of long-term radiation effect, the events of using water extracted from a well after the migration of radionuclides in groundwater (groundwater migration scenario on use of well water) are additionally considered here. These four scenarios are respectively divided into exposure pathways describing the activities of specific individuals as shown in TABLE I. Humans in the pathways may be exposed to external radiation, inhalation of radioactive particles and ingestion of foodstuffs containing radionuclides. Some exposure pathways due to the inhalation of radon gas, which are distinctive in the disposal system of uranium wastes, are also included in these scenarios.

TABLE 1:
DESCRIPTIONS OF SCENARIOS AND EXPOSURE PATHWAYS IN THE SHALLOW-LAND DISPOSAL OF URANIUM WASTES

Scenario	Exposure pathways	Exposed individual
Construction scenario	External exposure with house construction	Construction worker
	Inhalation of contaminated particles with house construction	Construction worker
	Inhalation of radon gas emanated from the site under construction	Construction worker
Residence scenario	Ingestion of crops cultivated in the disposal site	Resident
	External exposure with residence	Resident
	Inhalation of radon gas emanated from the site with residence	Resident
Groundwater migration scenario on use of river water	Ingestion of river water	Consumer
	Ingestion of radon released through the use of river water for living	Resident
	Ingestion of freshwater products caught in the river	Consumer
	Ingestion of livestock grown with river water	Consumer
Groundwater migration scenario on use of well water	Ingestion of well water	Consumer
	Ingestion of crops cultivated with well water	Consumer
	Ingestion of livestock grown with the feeds cultivated with well water	Consumer
	External exposure with agriculture	Farmer

DETERMINISTIC ASSESSMENT METHODOLOGY

The main procedure to evaluate the individual doses for the site-reuse scenario and groundwater migration scenario consists of the estimates for:

- Release rates of radionuclides from the disposal facilities and quantities of radionuclides remaining in the facilities.
- Migration of radionuclide with groundwater leached from the facilities and concentration of radionuclide in the river and well water.
- Concentration of radionuclide remaining in soil cultivated with the well water.
- Movement of radon in porous materials such as the waste and soil, and concentration of radon in the outdoor and indoor space.
- Individual doses for each exposure pathway.

Assuming the radionuclides are released on the basis of distribution equilibrium, the radionuclides fluxes from the facilities and the quantities of radionuclides remaining in the facilities are calculated by dynamic compartment model. This model is described by the following simultaneous ordinary differential equations:

Equation (1):

$$\frac{dC_{w,i}}{dt} = -(\eta_i + \lambda_i)\cdot C_{w,i} + \lambda_{i-1}\cdot C_{w,i-1} \tag{1}$$

where $C_{w,i}$ is the amounts of radionuclide i in the disposal facilities, η_i is release rate of radionuclide i, and decay constant of radionuclide i. The release rate η_i is given by the following Equation (2):

$$\eta_i = \frac{p}{H_w\cdot(\varepsilon_w + \rho_w\cdot Kd_{w,i})} \tag{2}$$

where p is infiltration rate, H_w is thickness of waste layer, ε_i is porosity of waste layer, ρ_w is bulk density of waste layer and $Kd_{w,i}$ is distribution coefficient of radionuclide i in waste layer. The released radionuclides migrate through a saturated zone with groundwater and flow to the water body such as a river. The migration of radionuclides is estimated from solving the 1-D advection dispersion equation. The concentration in the river and well water, which is used for drinking, agriculture, and etc., is calculated taking account of mixing with contaminated and non-contaminated water volume. The concentration of radionuclide remaining in cultivated soil owing to using the well water is calculated from the application of the dynamic compartment model to the cultivated soil layer under the input condition of estimated concentration in the irrigation water.

The calculations of the radon impact use the following models to estimate the rates of radon emanation from the wastes and the soil mixed with the wastes containing Ra-226. Generally, the radon exhalation rate from a soil into open atmosphere depends on many environmental factors such as water content and particle size of the soil, wind velocity etc. Assuming a homogenous radium distribution in the waste layer, the radon flux density is obtained by use of the following Equation (3):

$$J_w(t) = C_{Ra}(t)\cdot\rho_w\cdot F\cdot\lambda_{Rn}\cdot\sqrt{\frac{D_w}{\lambda_{Rn}}}\cdot\tanh\left(X_w\Big/\sqrt{\frac{D_w}{\lambda_{Rn}}}\right) \tag{3}$$

where J_w is radon flux density at the upper surface, $C_{Ra}(t)$ is Ra-226 concentration in the waste layer at time t, F is emanation factor, λ_{Rn} is decay constant of 222Rn, D_w is effective diffusion coefficient of Rn-222 in the waste layer, and X_w is thickness of the waste layer.

If non-contaminated soil is covered with the waste layer, the radon flux density into open air is represented by the following Equation (4):

$$J_c(t) = J_w(t) \cdot \exp\left(-X_c \Big/ \sqrt{\frac{D_c}{\lambda_{Rn}}}\right) \tag{4}$$

where, J_c is radon flux density into open air, X_c is thickness of the covered soil, D_c is effective diffusion coefficient of Rn-222 in the covered soil. The concentration of Rn-222 in outdoor air, which is emanated from a finite area such as the disposal area, is described by the following Equation (5):

$$\frac{\partial C_o(t)}{\partial t} = \frac{J_c(t)}{H} - \left(\lambda_{Rn} + \frac{U}{L}\right) \cdot C_o(t) \tag{5}$$

where $C_o(t)$ is radon concentration in outdoor air, H is height of open space, U is wind velocity, and L is length of emanation area toward the velocity direction. The solution of this equation with the initial condition $C_o(0) = 0$ is given by the following Equation (6):

$$C_o(t) = \frac{J_c(t) \cdot \left[1 - \exp\{-(\lambda_{Rn} + U/L\} \cdot t\right]}{H \cdot (\lambda_{Rn} + U/L)} \tag{6}$$

The concentration of radon in indoor air is used for the estimate on the inhalation of radon gas for the resident. It depends on the design and construction of the building structure, on meteorological parameters, and on the living habits of the occupants, which can affect the air exchange rate in the building [3]. Most of the houses in Japan have a vented crawl space, in which the height should be more than 45 cm according to the Building Standards Act in Japan. Considering the house construction and living habits in Japan, the estimates of the Rn-222 concentration in a house is based on the following:

- Radon concentration in the house is determined by two infiltrations. One is the infiltration with the ventilation from windows, and another is the distribution infiltrated through the crawl space.
- In addition, the concentration in the crawl space is calculated by the summation of both the emanated concentration from the underlying soil and the infiltrated concentration from a ventilating opening in the crawl space.

These concentrations are estimated from the equations, which are on a mass balance of radon gas in indoor space or the crawl space, respectively such as Equation (5). Radon gas may be released from water to air due to using the contaminated water in a house. The radon concentration is expressed by as follows [3], [4]:

$$C_i(t) = \frac{C_w(t) \cdot Q \cdot G}{V \cdot (\lambda_{Rn} + \lambda_i)} \tag{7}$$

where $C_i(t)$ is radon concentration due to water degassing, $C_w(t)$ is radon concentration in the water used for living, Q is the amount of water used per unit time, G is the degassing efficiency and V is the volume of the reference house. Finally, individual doses owing to external radiation, inhalation of radioactive particles, ingestion of foodstuffs containing radionuclides, and the inhalation of radon gas are calculated based on the estimated concentration for the radionuclides in the disposal site, the cultivated soil, the river and well water, air etc.

Probabilistic Assessment Methodology

In the deterministic analysis, the individual dose for the exposure pathway is calculated using a conservative or realistic value for each parameter. However, most of the parameters have their uncertainty and variability. To estimate the influence of parameter uncertainty in the long-term assessment for uranium wastes, we have developed a probabilistic assessment methodology. In this study, the probabilistic analyses for the residence scenario, which result in a critical scenario from the deterministic analyses, are performed for the quantitative estimate of the parameter uncertainty. Probabilistic assessment code system consists of a parameter sampling code, the assessment code for site-reuse scenario, and a statistical analysis code. The Latin Hypercube Sampling (LHS) method is used for sampling of parameter sets on the basis of Monte Carlo technique [5]. The Probability Density Function (PDF) with the definition of variable range and distribution type describes the variability of each parameter. The PDFs in the parameter sampling code are defined by four kinds of distribution type, uniform, log uniform, normal and lognormal. In the PDF of log uniform or lognormal distributions, the minimum and maximum values for the parameter are treated as the values of 0.1 percentile and 99.9 percentile in the PDF respectively. At the first step of probabilistic analysis, the parameters, which may bring the uncertainty and variability, are picked up, and the PDF is defined for each parameter. The next step, the parameter sets are generated by the LHS method. The probabilistic calculations of the individual doses for the sampled data sets are carried out using the same models as the deterministic analysis. The statistical analysis code is applied to the peak dose associated with the sampled parameter sets. The consideration on the statistical results such as scatter plot, Cumulative Distribution Function (CDF), Complementary Cumulative Distribution Function (CCDF) of peak dose values etc. leads to evaluation of parameter uncertainty and variability. In addition, parameter sensitivity or importance can be estimated from the consideration of partial rank correlation coefficients (PRCCs) for each sampled parameter against peak dose values.

Safety Analyses

Assumptions and Parameters

In this analysis, initial inventory in uranium wastes is determined from the level of the representative enrichment 4.5% used in Japan. On the basis of specific activity values for uranium at various levels of enrichment in the IAEA's report [6], the ratios of specific activity for U-238, U-235 and U-234 are estimated to be 0.13, 0.04 and 0.83, respectively. The analyses are carried out for the radionuclides with half-life of more than 10 days, including in 4N+2 and 4N+3 chains. For the daughters with half-life of less than 10 days, their dose conversion factors are added to those of their parents, assuming to be in radioactive equilibrium with their parents. Internal dose conversion factors for ingestion and inhalation are cited from ICRP publication 68 [7], and external dose conversion factors of radionuclides are calculated using QAD-CGGP2 [8]. Parameters associated with the disposal facilities, groundwater, geosphere, exposure pathways are chosen based on the parameters used in the NSC's report [1]. The values of distribution coefficient and transfer factors to foodstuffs are basically cited from IAEA TRS 364 [9]. Parameters on radon migration refer to the values in the UNSCEAR's reports [2], [3], and parameters such as house scale, air exchange rate, infiltration rate from the floor, etc. are determined by the data on Japanese house construction. The safety analyses for site-reuse scenario are performed under two assumptions: one is the conservative assumption taking account of no release of radionuclides from the facilities over long time scales and another is the realistic assumption taking account of release rates of radionuclides from the facilities.

Uncertainty of Input Data

On the basis of the results of the deterministic analyses, the probabilistic analyses are carried out for the important scenario, residence scenario, including the following exposure pathways:

- Ingestion of crops cultivated in the disposal site,
- External exposure with residence, and
- Inhalation of radon gas emanated from the site with residence.

Major PDFs for variable parameters, which are used in calculations of those three pathways, are shown in Table 2. The PDFs for the parameters are defined from the review of existing reports such as IAEA TRS 364 [9] and the consideration of natural and social conditions in Japan. Some parameters, amount of uranium wastes, plugging ratio of waste material, thickness of covered soil and height of crawl space, are treated as the fixed parameters in the probabilistic analyses. In the estimate of external exposure with residence, it is considered that external dose conversion factor for each radionuclide may depend on the uncertainty for thickness of borrowed soil, which is a non-contaminated soil for house construction. This probabilistic analysis system provides data library with respect to the external dose conversion factor corresponding to the variability of the thickness. The conversion factor associated with the thickness of borrowed soil is calculated using the interpolation [10].

Results of Deterministic Analysis

The results of safety analyses for specific activity 1.0 Bq/g of total uranium with enrichment 4.5% are shown in Figure 1 (a) and (b). Figure 1 (a) indicates the calculated individual dose for four scenarios (construction scenario, residence scenario, groundwater migration scenario on use of river water and well water). The dose history in each scenario is summed up from the results for the exposure pathways including in each scenario, as shown in TABLE I. These analyses are extended to times beyond the highest value of the dose (maximum dose). In the case of no-released radionuclide from the disposal facilities, the dose in residence scenario is the highest and its maximum dose of around 2.2E-4 Sv/y is reached about two hundred thousand years after the disposal. The component of total dose in residence scenario is shown in Figure 1 (b). The exposure for inhalation of radon gas with residence is the most critical in this scenario because of increasing radon concentration in the site depending on the accumulated concentration of Ra-226. The doses derived from Pb-210 and Ra-226 are dominant, respectively in Ingestion pathway of cultivated crops and in external exposure pathway. This result indicates that the dose evaluation in residence scenario is of great importance in the safety assessment owing to the influence of daughters built up by uranium decay chain. Considering the release rates from the disposal facilities as realistic assumption, the maximum dose in residence scenario decreases to about 8.0E-6 Sv/y. The results for residence scenario are sensitive to the release condition of radionuclides from the facilities over long-term period.

Viewed from scenario uncertainty on the estimate of long-term radiation effect, the dose calculations in groundwater migration scenario were performed for use of both river water and well water in a biosphere. The calculated dose for use of well water is about three orders of magnitude greater than that for use of river water. This is based on the difference of flow rates between well and river. The dose history in the case of well water indicates two peaks at four hundred years and at thirty thousand years. The former is the peak dose derived from U-234, the latter is the one derived from its daughters. The maximum dose for use of well water is about 5.0E-5 Sv/y. Under the realistic assumption taking account of release rates of radionuclides from the facilities, the maximum dose for use of well water is higher than that in residence scenario. Therefore, the scenario uncertainty on use of the contaminated water in a biosphere over long time scales has a great influence on the dose calculation.

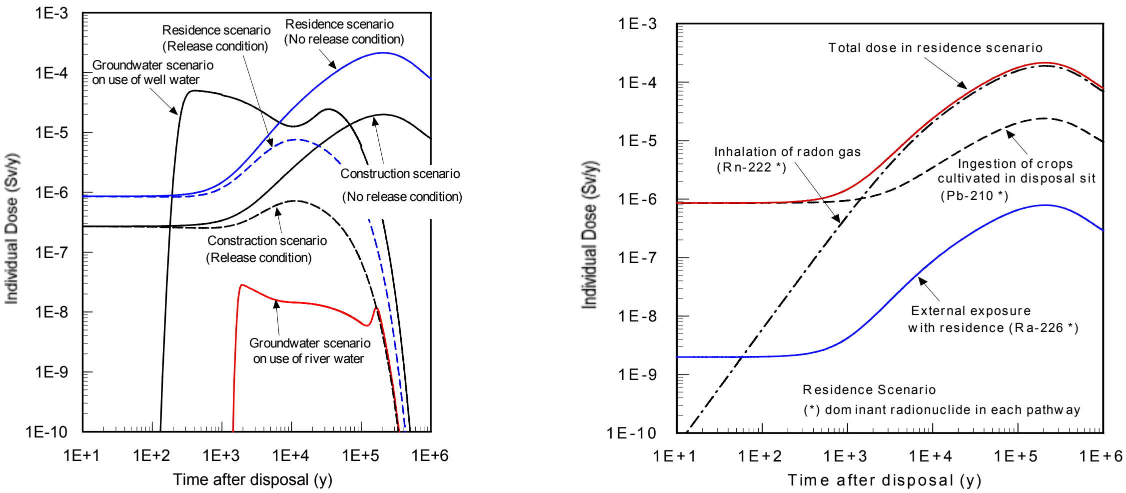
TABLE 2:
MAJOR PDFS FOR VARIABLE PARAMETERS IN RESIDENCE SCENARIO

Parameter	Unit	Deterministic value	Distribution type	Minimum value	Maximum value
Parameters on the disposal facilities					
Amount of uranium wastes	m^3	100,000	Constant	-	-
Width of waste layer	m	350	Calculation*1	-	-
Length of waste layer	m	350	Uniform	70	700
Thickness of waste layer	m	5	Uniform	1	10
Plugging ratio of waste material	-	0.163	Constant	-	-
Bulk density of disposal site	g/cm^3	2	Uniform	1	2.3
Porosity of disposal site	-	0.2	Normal	0.15	0.3
Infiltration rate into waste layer	m/y	0.4	Lognormal	0.1	1
Start time of radionuclide release after closure	y	0	Uniform	0	300
Thickness of covered soil	m	1.8	Constant	-	-
Depth of excavation	m	3	Uniform	0.5	10
Thickness of borrowed soil	m	0.3	Uniform	0	1
Parameters on external exposure pathway					
Annual exposure time	h/y	8760	Normal	3000	8760
Shielding factor in residence	-	0.2	Uniform	0	0.66
Parameters on ingestion of crops cultivated in the disposal site					
Absorption factor from plant root*2	-	1	Loguniform	0.002	1
Ingestion rate of rice	kg/y	71	Normal	0	149
Ingestion rate of green vegetable	kg/y	12	Normal	0	36
Ingestion rate of root crop	kg/y	45	Normal	0	139
Ingestion rate of fruit	kg/y	22	Normal	0	81
Dilution factor of crops in a market	-	1	Uniform	0	1
Parameters on inhalation of radon gas emanated from the disposal site					
Emanating power	-	0.2	Lognormal	0.01	0.8
Radon diffusion coefficient in waste layer	m^2/s	2.0E-06	Lognormal	1.0E-10	3.0E-06
Radon diffusion coefficient in covered soil	m^2/s	2.0E-06	Lognormal	1.0E-10	3.0E-06
Radon diffusion coefficient in borrowed soil	m^2/s	2.0E-06	Lognormal	1.0E-10	3.0E-06
Height of outdoor space	m	3	Uniform	1	5
Length of emanation area	m	180	Uniform	70	700
Wind velocity	m/s	3	Normal	1.4	5.5
Air exchange rate in crawl space	m	0.45	Constant	-	-
Height of crawl space	s^{-1}	9.9E-04	Lognormal	5.6E-05	3.1E-03
Air exchange rate in indoor space	s^{-1}	1.1E-04	Lognormal	1.4E-05	1.4E-03
Height of indoor space	m	2.5	Loguniform	2	5
Radon infiltration rate through the floor	s^{-1}	1.0E-04	Lognormal	1.4E-06	1.0E-04
Equilibrium factor in indoor space	-	0.4	Normal	0.1	0.7
Equilibrium factor in outdoor space	-	0.8	Normal	0.1	1
Ratio of outdoor living	-	0.2	Uniform	0	0.66
Annual exposure time	h/y	8760	Normal	3000	8760

*1) This value is calculated from the sampled size of waste layer and constant values of waste volume and plugging

*2) This factor accounts for the ratio of root which reaches the waste layer and absorbs radionuclides.

FIGURE 1:
RESULTS OF DETERMINISTIC ANALYSES: (A) INDIVIDUAL DOSES FOR FOUR SCENARIOS, (B) INDIVIDUAL DOSES FOR THREE EXPOSURE PATHWAYS IN RESIDENCE SCENARIO UNDER NO RELEASE CONDITION FROM THE DISPOSAL FACILITIES.

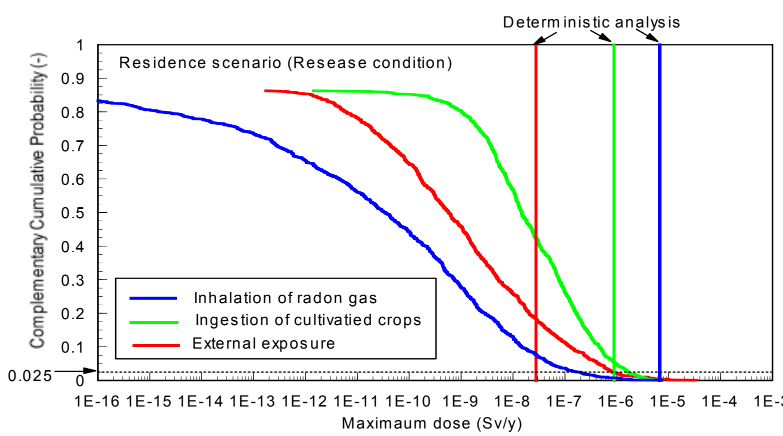


(a) Four scenarios *(b) Exposure pathways in residence scenario*

RESULTS OF PROBABILISTIC ANALYSES

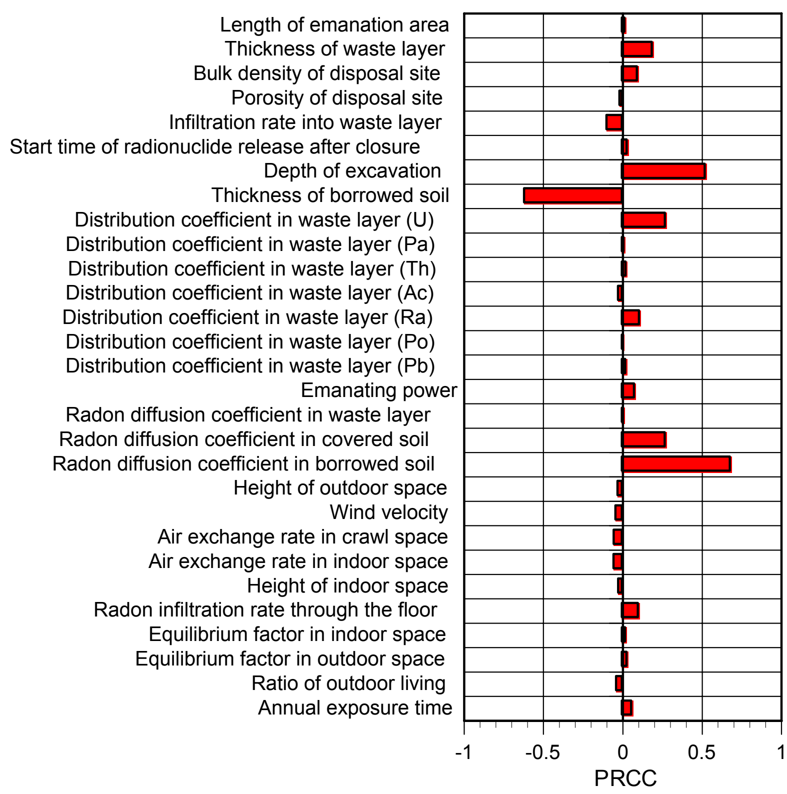
Figure 2 shows the CCDFs of the maximum dose in residence scenario, derived from statistical analysis for one thousand sets of sampling parameter. This figure presents the comparison between the deterministic and probabilistic results under the release condition of radionuclides from the facilities. Compared with the CCDFs profiles in the exposure pathways, the variability of the maximum dose for inhalation of radon gas is larger than those for the other pathways in residence scenario. This means that the influence of parameter uncertainty is the most remarkable in the estimation for the inhalation of radon gas with residence. The peak doses from deterministic analysis except for radon inhalation exposure lie between the median and the 2.5th percentile value corresponding to the upper endpoint of the 95% confidence interval. However, the deterministic peak dose in radon estimate is higher than the 2.5th percentile value of the peak dose from the probabilistic calculation. From this comparison, it is considered that the result of the deterministic analysis for the inhalation of radon gas is evaluated from a conservative parameter set.

FIGURE 2:
THE CCDF OF PEAK DOSE IN SITE-REUSE SCENARIO



The parameter importance in each exposure pathway can be estimated from using the partial rank correlation coefficients (PRCCs) for each sampled parameter against peak dose values. The PRCC value is used as an indicator for the screening of parameter to the calculated peak doses. The absolute value of PRCC indicates the extent of parameter importance, and the correlation between the parameter and the dose is represented by plus and minus of PRCC value. Figure 3 shows the PRCC values of parameters used in the dose calculation for the inhalation of radon gas. The important parameters identified by high PRCC value are depth of excavation, thickness of borrowed soil, and diffusion coefficient of radon in the soils. The PRCC value for the distribution coefficient of uranium in waste layer is also high under the release condition from the facilities. The depth of excavation determines the mixing rate between the waste layer and the covered soil (non-contaminated soil), and this leads to its tendency of high PRCC value. The PRCC values for two parameters, thickness of the borrowed soil and radon diffusion coefficient in the borrowed soil, are especially high. This indicates that the parameters with respect to the diffusion migration of radon gas in the surface soil are of great importance in the radon estimate.

Figure 3:
PRCC values of parameters used in the dose calculation for inhalation of radon gas



Conclusion

The JAERI has developed the deterministic and probabilistic safety assessment system to estimate the long-term radiation effect owing to the shallow-land disposal of uranium wastes. The safety and uncertainty analyses for the waste disposal were performed using the developed deterministic and probabilistic safety assessment system. The results are summarized as follows:

The safety analysis shows that the dose evaluation in residence scenario is of great importance in the safety assessment owing to the influence of daughters built up by uranium decay chain. The dose in residence scenario is sensitive to the release condition of radionuclides from the facilities over a long-term period.

The uncertainty analysis based on the probabilistic methodology indicates that the influence of parameter uncertainty is the most remarkable in the estimation for the inhalation of radon gas with residence. The important parameters identified by high PRCC value are depth of excavation, thickness of borrowed soil, and diffusion coefficient of radon in the soils.

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(8) Y. Sakamoto and S. Tanaka, "QAD-CGGP2 and G33-GP2: Revised Versions of QAD-CGGP2 and G33-GP (Codes with the Conversion Factors from Exposure to Ambient and Maximum Dose Equivalents)", JAERI-M 90-110, JAERI, Tokyo, 1990.

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(10) A. Akima, "A New Method of Interpolation and Smooth Curve Fitting Based on Local Procedures", J. ACM, 17, 4, 1970.

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Attachment A: Presentations

Attachment A includes presentations from the following presenters:

- Antone L. Brooks
- Miroslav Pinak
- Ritsuko Watanabe and Kimiaki Saito
- Akira Endo, Yasuhiro Yamaguchi and Fumiaki Takahashi
- Shohei Kato
- Akihiro Sakai and M. Okoshi
- Robert Meck
- Hideo Kimura, Seiji Takeda, Mitsuhiro Kanno, and Naofumi Minase